

Binary Evolution in World Wide Web

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Abstract

We present a WWW-version of the *Scenario Machine* - a computer code designed to calculate the evolution of close binary stellar systems. The Internet users can directly access to the code and calculate binary evolutionary tracks with parameters at the user's will. The program is running on the *Pentium* server of the Division of the Relativistic Astrophysics of the Sternberg Astronomical Institute (<http://xray.sai.msu.su/>). The results are presented both in the form of tables and graphic diagrams. The work is always in progress. More possibilities for Internet users are intended to become available in the near future.

1 Introduction

The Scenario Machine method to calculate evolution of binary stars is basically a Monte-Carlo method for statistical simulation of large ensembles of stellar binary systems originally used by Kornilov & Lipunov (1983) for massive binaries and developed later by Lipunov & Postnov (1987) for low-mass binaries (for the most recent review, see Lipunov, Postnov & Prokhorov, 1996 (LPP96)). The method is based on the construction of a great number of single evolutionary tracks with different initial conditions.

Although the present WWW-version of the Scenario Machine includes only the single-track constructor, it allows one to make quickly the evolutionary track of a close binary system with arbitrary initial parameters, such as masses of the components, orbital separation, orbital eccentricity, magnetic fields of compact stars, etc., as well as using different types of evolutionary scenarios (with different distributions of the kick velocity imparted to a newborn neutron star, high- or low-mass stellar wind loss during main sequence evolution, etc.).

This is not the first example of the WWW representation of the stellar evolution. In 1995, the Goettingen group made available direct calculations of single stars evolution with parameters determined by the user on their WWW-server (<http://www.uni-sw.gwdg.de/~jloxe/wwwgal/>). In contrast, our code affords for the first time the calculation of *binary* evolutionary tracks.

2 The Model

In the calculations of the evolutionary track both nuclear evolution of the normal star and spin evolution of a magnetized compact object (neutron star (NS) or white dwarf (WD)) are taken into account.

2.1 Normal star evolution

We consider stars with a constant (solar) initial chemical composition. Before the Roche lobe overflow, the components evolve as single stars (see for details LPP96). Analytical approximation describing evolutionary tracks are used. For massive stars, we use two types of evolutionary tracks: those calculated

by the Geneva group (Schaller et al., 1992) with high stellar wind mass-loss (up to 90 per cent of the initial mass), and those calculated earlier by different groups assuming low stellar wind mass-loss (up to 30 per cent of the initial mass).

When a star fills its Roche lobe, the mass transfer time-scales are treated differently depending on the star’s mass and time it fills the Roche lobe. For the most close binaries we also calculate Roche lobe overfilling due to angular momentum loss by magnetic stellar wind or gravitational radiation.

If the mass transfer onto a normal star occurs on a time-scale ten times shorter than the thermal Kelvin-Helmholtz time for this star or a compact star is engulfed by a giant companion (e.g. as a result of the kick), the common envelope (CE) stage of the binary evolution is set in (Paczynski 1976). The CE stage is treated conventionally by introducing a parameter α_{CE} that measures what fraction of the system’s orbital energy goes, between the beginning and the end of the spiralling-in process, into the binding energy (gravitational minus thermal) of the ejected common envelope. Spiral-in during the CE stage can result in the binary coalescence. In the case of coalescence of the normal star with a compact object (NS or BH) a Thorne-Zytkow object is formed.

2.2 Initial parameters of compact stars

The stars with initial masses $M \leq 10M_{\odot}$ leave a WD in the end of evolution, with the WD masses and chemical composition depending on the binary system’s parameters. Stars with $10M_{\odot} < M < M_{cr}$ collapse to form NS of $1.4 M_{\odot}$; when $M > M_{cr}$ a BH with a mass of $M_{bh} = k_{bh}M_*$ is formed, where M_* is either the mass of the pre-collapsing star (in the case of low stellar wind mass-loss scenario), or the initial mass of the star (in the case of the high stellar wind mass-loss scenario). NS and WD are assumed to have a magnetic field randomly distributed within a range $10^5 - 10^9$ G and $10^8 - 10^{13}$ G correspondingly.

The evolution of a compact star is considered as the change of its spin period and hence the change of regime of interaction with the surrounding plasma supplied by the second component (for more detail see Lipunov 1992, Lipunov & Popov 1995).

The accretion rate is limited by the Eddington luminosity or by the surface nuclear burning of the accreted matter (for WD). In that case supercrit-

ical regimes with mass outflow may happen.

When an accreting WD reaches the Chandrasekhar limit, it assumes to explode as a SN type Ia with or without NS formation. Analogously, after reaching the Oppenheimer-Volkov limit, a NS collapses into a BH.

3 World Wide Web version

The World Wide Web version provides the opportunity to construct an evolutionary track with all important parameters determined by the user at will from a broad range of available values.

Some of the most unclear branches of the scenario can also be determined by the user. They include: the type of mass-loss of normal star, the level of conservativeness of the matter captured by the compact companion, the upper limit of the accretion rate at the CE stage by the compact object, switching of the accretion-induced magnetic field decay, etc.

Below we describe briefly how to handle the code, what the WWW-pages contain and how the results are presented.

3.1 WWW access

The code is located on the WWW-server of the Division of Relativistic Astrophysics of the Sternberg Astronomical Institute. The URL is <http://xray.sai.msu.su/sciwork/scenario.html>. The server quickly calculate the track so the waiting time is short.

3.2 Page contents

On the main page, a very short description of the program may be found.

From the main page three following items are available:

1. "Go to the evolutionary track constructor"
2. "How all this stuff work?"
3. "Credits"

The first link brings the user to a very friendly interface of the main code, where all parameters can be set and the calculations can be started.

The second link provides a list of papers containing the results of the Scenario Machine calculations beginning from 1983 until 1996 and a short description of the code.

The third link gives some information on the authors of the code and its WWW-version.

3.3 Presentation of the results

The results are presented in forms of tables and diagrams chosen by the user at will. Part of the table and a cartoon figure of the track calculated for the default set of the initial parameters are shown in Fig. 1 and 2.

In the future, we intend to make available calculations of a large number of binary systems assuming different initial distributions, chemical composition, etc., to construct a "Galaxy at will", as well as various interface facilities.

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References

- [1] Kornilov V.G. and Lipunov V.M., (1983) AZh, vol. 60, p. 284
- [2] Lipunov, V.M. and Postnov, K.A. (1987) AZh, vol. 64, p. 773
- [3] Lipunov, V.M. (1992) "Astrophysics of Neutron Stars", Springer Verlag, Heidelberg
- [4] Lipunov, V.M. and Popov, S.B. (1995) AZh vol. 72, p. 711
- [5] Lipunov, V.M., Postnov, K.A. and Prokhorov, M.E. (1996), Review of Astrophysics and Space Science, Ed. R.A.Sunyaev, Harwood Acad. Publ., vol.17, pp.1-160

- [6] Paczyński, B. (1976) In: "Structure and Evolution of close binary systems", IAU Symp. No. 73, eds. P.P.Egglton, S.A.Mitton and J.A.J.Whealan, Reidel, Dordrecht, p. 75
- [7] Schaller, G., Schaerer, D., Meynet, G. and Maeder, A. (1992), A&AS, 96, 269